SCHWING

A Fertility Study of the Strawberry in Pot Cultures

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A FERTILITY STUDY OF THE STRAWBERRY IN POT CULTURES

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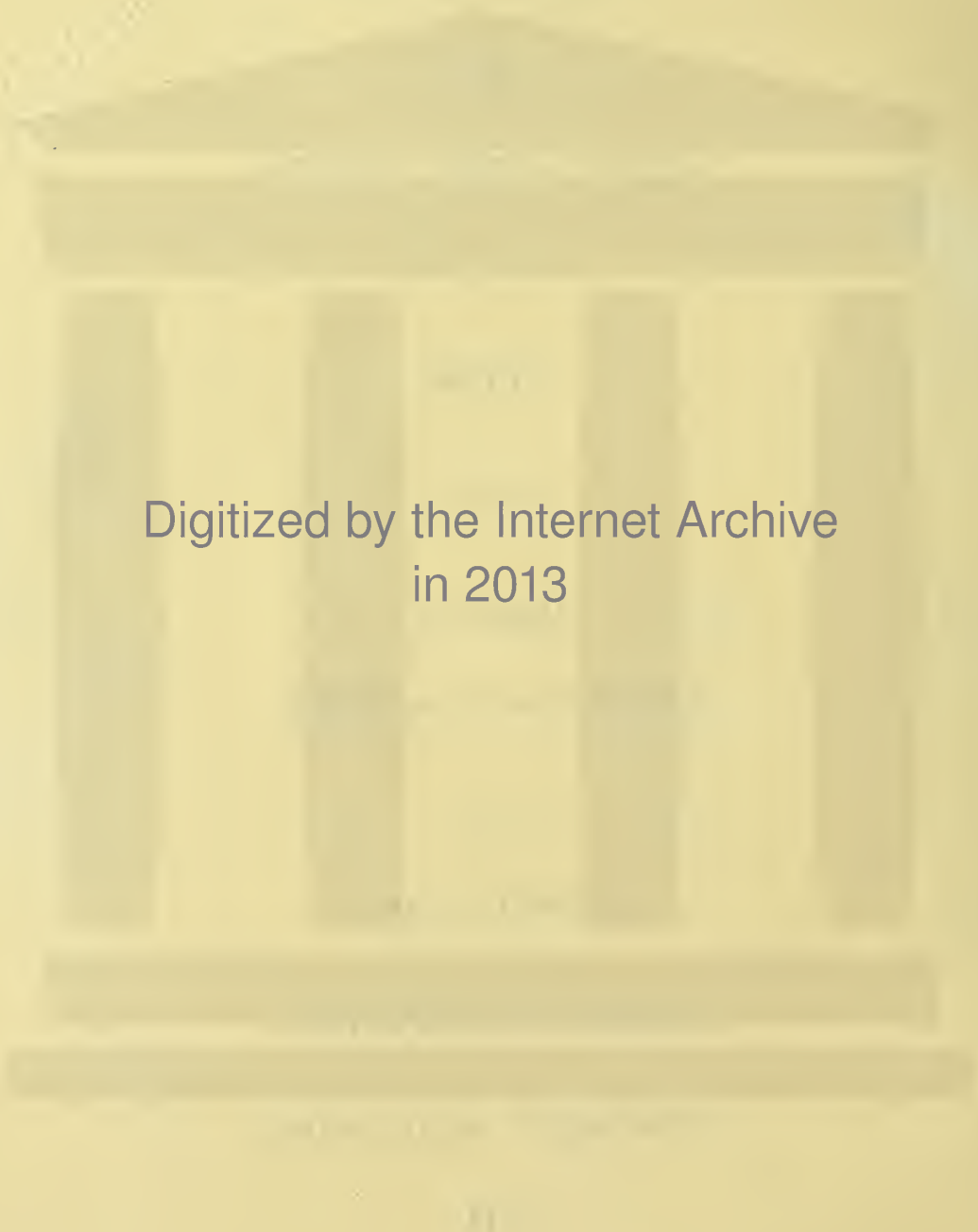

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THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

Edward Albert Schwing

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IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

DEGREE OF Bachelor of Science in Agriculture

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C O N T E N T S

A FERTILITY STUDY OF THE STRAWBERRY IN POT CULTURES

INTRODUCTION

To a great extent experimentation with the strawberry has been carried on with field plots subjected to field conditions. But much can be learned from pot cultures where the conditions are regulated. Losses such as are sustained under outdoor conditions are preventable and results can be interpreted more easily where the causes can be discovered with greater accuracy. Where fertility is involved, the experimenter must have his work under control to secure best results.

The subject of this thesis is original. Its conclusions are to be drawn from the results of actual experimentation. The investigation was carried on under the direction of Professor C. S. Crandall of the Horticultural Department, to whom the writer is indebted for many suggestions.

The thesis is to be divided into several main topics. The literature on the subject will be briefly discussed, the object and the method of procedure will be stated, the data will be set forth, and conclusions will be drawn from the data obtained.

LITERATURE ON THE SUBJECT

A few words about the strawberry will not be out of place in spite of the numerous discussions of this plant in books, periodicals, and bulletins. The common garden variety is Fragaria chiloensis, which was first native of Chili, brought to France, later to England, and eventually to the United States, where it was crossed with other varieties. The strawberry will thrive on almost any soil and is successfully cultivated in all parts of the United States. The various sections of the United States recommend different soils for the best results. For example, in New England a light soil is advocated because of the necessity of early crops. The market requirements of the middle eastern states also demand a light soil for quick returns. The South prefers a heavy soil, because of the rapid loss of moisture from the lighter soils and because a later crop is desirable. The Rocky Mountain states favor the light soils because the heavy soils bake under the irrigation system. The coast states prefer the light soils where irrigation is carried on and medium soils where normal rainfall is depended on. The Middle West prefers the medium weight soil with good drainage. Summarizing in brief tabular form:

Source	State	Soil	Reason
Bulletin 21	Maine	Warm, moist, sandy loam	Early maturity
" 137	New Hampshire	Medium soils	" "
" 33	Maryland	Virgin soil	Quick returns, early maturity
" 126) Report 1891)	New Jersey	Sandy loam	Quick returns, good market
Bulletin 75	Mississippi	Heavy soils	Holds moisture
" 39	Florida	Good soil, clay subsoil	" "
" 94	Alabama	Heavy soil	" "
" 140,29	Colorado	Sandy loam	Does not bake when dry, free of alkali
" 70	Idaho	" "	No baking after irrigation
" 47	Arizona	" "	" " " "
" 54	Ohio	Well drained, medium weight soil	Thrives best

The soil must be well prepared for the seed bed. A precaution that is well worth following is not to choose a field that has been in sod on account

of the damage that is likely to be caused on the young plants by the grub-worm. The field must be well drained. It is well to bear in mind that the strawberry is cultivated intensely and intense methods must therefore be applied.

The literature of all experiment stations and agricultural agencies agree that some fertilizer is to be recommended, but they diverge greatly in their recommendations. Professor Bailey, in the New York Cornell Bulletin 189, summarizes his extensive experiments with fertilizers as follows:

"The first striking fact about these tests is the high yield of the fertilizer plats. Omitting, experiment 3, in which part of the plants were killed by the fertilizer and in which the soil was very poor and stony, the average yield from 55 tests was 5197 quarts per acre, or 2000 quarts above the average. The second general result is the superiority of the potassium and phosphoric fertilizers as compared with the nitrogenous. The nitrogen fertilizers, including very heavy applications of stable manure, gave too much growth and an inferior quality of fruit. It must be remembered, however, that these strawberry growers are good cultivators and that their tillage probably supplied sufficient nitrogen in most cases."

Professor Bailey carried on a very extensive experiment in co-operation with a large number of strawberry growers throughout New York. Potassium, nitrogen, and phosphorus in varying amounts were used.

New Jersey is one of the leaders in strawberry work. Extensive experiments have been carried out on plots for a long series of years. In the Report for 1891, it was found that 1000 lbs. of Kainit (125 lbs. actual potash) and 500 lbs. precipitated phosphate (150 lbs. available phosphoric acid) aided greatly in securing a larger crop. Nitrate of soda to the extent of 200 lbs. to the acre, finely ground and scattered broadcast when the leaves were dry just before bloom, caused deeper colored and larger leaves as well as stronger bloom. The increase due to these fertilizers was 31 per cent, mainly in the size of the fruit. In the 1892 Report, New Jersey found that the addition of 200 lbs. of

nitrate of soda in the spring brought a gain of 18 per cent or $21 an acre. The conditions were such that the mineral elements were well supplied, the land was not heavy, and nitrogen had not been added in large amounts. Unless the mineral elements are in sufficient amounts, the nitrate of soda gives an increase in vine production at the expense of the fruit. The following table shows the results of adding the $NaNO_3$.

- 1892 -

No. of plot	Fertilizer per acre	Cost per acre	Yield per plot quarts	Yield per acre quarts	Value per acre	Net value per acre	Net Gain
1	150 lbs. $NaNO_3$ 500 " ground bone) 1000 " kainit)	$14.87	376	1880	$141	$126.13	--
2	Same plus 360 lbs. $NaNO_3$	19.37	444	2220	166.50	147.13	$21

- 1893 -

							Gain (Net) for two years
1	Same as 1 (1892)	14.87	142	710	88.20	211.33	--
2	Same as 2 (1892	22.97	172	860	103.20	246.73	$35.40

Again in 1895, a spring top dressing of sodium nitrate was found to give a good gain. In 1897 and 1898, the nitrate of soda was found to give a darker foliage and freedom from the rust which attacked the plants which had not been treated with $NaNO_3$.

From the "Journal of Horticulture" printed in London the following statement is found. "The effect of nitrate of soda on strawberries, especially in light soils, is magical, doubling and trebling the yield. Try a large dressing of nitrate of soda on an old strawberry bed, first of all freeing it from weeds and grass. Sow it powdered broadcast early in the spring and give another dressing a few weeks later. The effect will be also to kill slugs and other predatory pests that fatten on strawberries, which is an important consideration. The best time to apply nitrate of soda to strawberries is when they are commencing growth, and if more stimulus is needed supply another dressing after the fruit is well set. Scatter it between the rows and plants It is desirable

to use superphosphate as well as nitrate of soda on strawberry plantations, for the one tends to the production of fruit and the other swells it to large and handsome proportions."

Georgia, In Bulletin 48, found that kainit paid as a crop producer and also as an insecticide. It was also found that acid phosphate, muriate of potash, and $NaNO_3$ are valuable fertilizers. In Bulletin 32, Georgia lays emphasis on the turning under of cowpeas, the liberal application of manure, and a top dressing of 150 lbs. of nitrate of soda in the spring.

Ohio Bulletin 5 states that manure gives very good results, that $NaNO_3$ gives a better growth of foliage but decreases the quantity of fruit, and that the superphosphate ripens the fruit earlier. In Bulletin 54 it is found that well rotted manure, bone meal, and wood ashes are the best fertilizers.

Bulletin 33, Maryland, gives the following fertility directions: "By plowing under crimson clover and fallow cow peas the moisture of the soil would be conserved. A good manure is also secured." The following applications are also recommended.

Fertilizer for New Beds

Work in with the cultivator before setting.

Dissolved South Carolina rock - - - - - - -	1000 lbs.
Fine ground dried fish or tankage - - - - -	600 "
Nitrate of soda - - - - - - - - - - - - - -	100 "
Muriate of potash - - - - - - - - - - - - -	300 "
	2000 "

Fertilizer for Old Beds

Sow along the rows close to the plants and work in.

Dissolved South Carolina rock - - - - - - -	1100 lbs.
Dried blood - - - - - - - - - - - - - - - -	200 "
Nitrate of soda - - - - - - - - - - - - - -	400 "
Sulphate of potash - - - - - - - - - - - - -	300 "
	2000 "

Bulletin 29, Colorado, states that potash and bone phosphate are the best fertilizers. Nitrate of soda in the spring does good work in increasing the yield. Manure is good, but it aids in weed production unless it is well rotted. In Bulletin 140, the recommendation is from ten to twenty loads of good

barnyard manure to the acre with bone meal and nitrate of soda, the latter at blooming time.

Alabama and New Hampshire also advocate fertilizing, in Bulletins 94 and 137 respectively. Missouri Bulletin 113 claims much for acid phosphate in the form of steamed bone meal to be used one year before the crop is to be harvested, but nitrogen or potassium fertilizers are not recommended, as losses resulted where these were added.

From the experimental data and recommendations then, we infer that strawberries should be fertilized and that fertilizing will be profitable if it is used with care and judgement. One point that cannot be brought out too strongly is that the organic supply of the soil should be maintained. The amounts and the kinds of fertilizers used should be governed by the soil on which the crop is to be raised. It would be folly from a commercial standpoint to supply food to a soil which is already richly supplied with that particular plant food. Very often the plants are killed by such treatment, a fact which will be brought out later. At least it has a retarding action on the plants. Of the plant foods, the elements that are ordinarily lacking are nitrogen, phosphorus, and potassium. Nitrogen is most available in the form of $NaNO_3$, but this form of food must be used with caution to prevent serious injury to the foliage. It should be added in small amounts at the blooming time, and at other critical periods of plant growth if it be necessary. Raw or steamed bone furnishes three to six per cent, ground fish from seven to eight per cent, and tankage from four to twelve per cent. These other forms of plant food are not as available as $NaNO_3$, so it is a good practice to apply another source of nitrogen along with $NaNO_3$, which is used up immediately and leaves no surplus. Phosphorus is obtained chiefly from bone meal (about fifteen to twenty-five per cent. available phosphoric acid) or from the rock phosphates (about twelve per cent. available phosphorus). Muriate of potash is the most common form of potassium used, with sulphate of potash and kainit in close approximation. Kainit has about twelve per cent. of potassium.

Nitrogen is also added in the form of green manures. This is the cheapest method, where the farming is not too intense. It also adds the necessary organic matter.

PURPOSE AND METHOD OF PROCEDURE

From the mass of data that has been taken by these various experimenters, there is nothing to indicate what amount of plant food the strawberry soil must contain for the best growth of foliage and fruit, and it is difficult to obtain this information from field plots where there are so many uncontrollable factors. To secure some definite information concerning this factor of plant growth, the author has undertaken an experiment which covers the period of growth of the strawberry from the dormant stage to the end of the fruiting of the first crop of berries. Time did not permit of the securing of data from the entire crop of the plants. But this was hardly necessary, as the data secured during this period would have added little to the results of the experiment.

The method of procedure was as follows: In all, thirty-two glazed surface pots were used. These pots were of about one gallon capacity each and were provided with drainage by a small hole at the side within an inch from the bottom of the pot. In this way thorough drainage was obtained and the least amount of plant food was lost. The material used for the plants to grow in was white Michigan sand, which on analysis (by the Agronomy Department) was found to contain no plant food save a trace of nitrogen.

The plant used for this experiment was the Gandy, which is a very productive and hardy plant. It is a late cropper and a very good shipper. It was chosen mainly for its hardiness, because a weaker plant would probably not survive the rigorous treatment of transplanting. The plant was taken up after a few light frosts had occured when it was at least partly in the dormant state. The plants were transplanted into the pots immediately on digging out of the field, that is after the data were secured. Uniformity in vigor and size were aimed at in the choice of plants. They were firmly planted in the pots and were immediately fed plant food diluted in distilled water.

All of the food received by the plants was added in the form of liquid solutions. The following solutions were used:

1 - NH_4NO_3 for nitrogen. 80 grams of NH_4NO_3 were dissolved in 2500 cubic centimeters of distilled water.
2 - $CaH_4(PO_4)_2$ for phosphorus. 25 grams of $CaH_4(PO_4)_2$ were dissolved in 2500 cubic centimeters of distilled water.
3 - K_2SO_4 for potassium. 50 grams of K_2SO_4 were dissolved in 2500 cubic centimeters of distilled water.
4 - $MgSO_4$ for magnesium. 20 grams of $MgSO_4$ were dissolved in 2500 cubic centimeters of distilled water.
5 - $FeCl_3$ for iron. .1 gram of ferric chlorid were dissolved in 250 cubic centimeters of distilled water.

These forms of solutions were chosen because they each contain as large an amount of the desired element as possible, do not contain any undesirable element, and are not injurious to plant growth if applied in diluted form. The sand and these solutions are used successfully by the Agronomy Department in its extensive pot culture investigations.

The food was applied weekly in diluted form.

There were five groups of pots of six pots each, and two check pots which received no treatment except distilled water. All of the first thirty pots received some plant food of every kind, but each group received a different amount of the food. At each application the following amounts were added:

To group I, consisting of pots 1 to 6 inclusive, 12 cc. of each of the first four solutions were added and 1.2 cc. of the last solution. Group II received five-sixths as much as group I, group III, two-thirds; group IV, five-twelfths; and group V, one-fourth.

Twenty-five applications were made in all, beginning November 17, and ending May 9. The last data was taken May 12. The plants were watered with distilled water throughout the experiment.

Just what fertility of soil will give the best growth to the plant and produce the most berries is the problem that is to be investigated. Grain does best with the results of group II, but at the time of preparation for the experiment it was decided that for strawberries it would be less and the groups were arranged according-

ly. But the data show that the amount is lower than the writer imagined.

During the period of experimenting the following amounts of food were used, in grams:

	NH_4NO_3	$CaH_4(PO_4)_2$	K_2SO_4	$MgSO_4$	$FeCl_3$	N	P	K
Group I	9.6	3.	6.	2.4	.012	3.36	1.05	2.10
Group II	8.	2.5	5.	2.	.01	2.80	.875	1.75
Group III	6.4	2.	4.	1.6	.008	2.24	.70	1.40
Group IV	4.	1.25	2.5	1.	.005	1.40	.44	.88
Group V	2.4	.75	1.5	.6	.003	.84	.26	.52

This would give, in terms of pounds to the acre for the half year of the experiment and for the full year, the following:

	Group I	Group II	Group III	Group IV	Group V
N, ½ yr.	1230	1006	805	503	302
P, ½ "	400	314	267	157	100
K, ½ "	800	628	534	314	200
N, 1 yr.	2560	2012	1610	1006	604
P, 1 "	800	628	534	314	200
K, 1 "	1600	1256	1068	628	400

Magnesium, iron, calcium, and sulphur are also important elements of plant food, but they are usually of such large amounts in the soil that they have no commercial value. Because of this fact we will not discuss these elements of fertility in the manner of the above table.

The groups are to be compared in all of the subsequent data and conclusions are to be drawn from the group results; the data will then be explained.

Data were secured on the leaf surface, on the crowns, on the root length, and on the first crop of berries from the plants. A record of the temperature and of the weather conditions was taken from time to time, but not with any definite regularity.

ERRORS THAT MAY HAVE OCCURRED

In an experiment of this nature there is much possibility of error, and mistakes are made in spite of the most careful manipulation. By means of the glazed surface pots and the use of distilled water with plant solution from corked bottles, there is very little error possible in the feeding of the plants. The small opening in the bottom of the pot permits of drainage and allows but little of the plant food to escape before it is fixed in the soil. The pots were bedded two thirds in ordinary sand. There is a chance that in the pots that received little food there may have been food taken up by osmosis through the small drainage hole, but this seems to have been very small or negligible as shown by the check pots that received no food. The largest errors were probably made in the securing of data. In measuring the leaf surface, the value is comparative and not real. The measurement was taken of each leaf by taking the length and breadth and multiplying one by the other for the area. This method may not be the best for ordinary measurement, but should be satisfactory for the comparison that we have undertaken as the leaves of all plants were measured in the same manner. Again, in determining the root area the error was large; here it was really greater than in the case of the leaves. The average length of the roots was taken and multiplied by the number of roots that the plant possessed, to secure the root length. As the small fibrous branchlets could not be taken into account in this scheme, the errors will be rather important. Taken as a whole, however, this method of measurement is probably as accurate for comparative purposes as any other method would be. In securing the data on the pollination and the ripening of the fruit there was a chance for slight variation, as the writer is not skilled enough in securing data of this kind to be accurate to the hour. A day's variation may have come into this phase of the work, but this is partly eliminated by the averaging up of the groups, where an error in one individual is balanced by an error in another individual. Other errors that are possible

are the difference in the vitality of the plants and the tearing of the root system. Perfection in these cases is impossible; the experimenter can but do his best to eliminate the sources of variation here. The writer selected plants as nearly alike as possible, and grouped them as uniformly as could be.

FACTORS IN THE EXPERIMENT

Conditions were favorable at the start; a week of warm, bright weather followed immediately after potting. The greenhouse temperature was about 75 to 80 degrees in the middle of the day. Wet, foggy weather with as low a temperature as 55 degrees prevailed from November 26 to December 3. The early weeks in December were about even in regard to the amount of good and bad weather, while the latter part of December and the early part of January was cold and wet, with practically no sunshine. Then followed a week of rather bright weather. During all of this time the day temperature was about 55 degrees and the night temperature about 50 degrees. The house in which the work was done was fitted to carry on sweet-pea experiments, and the strawberries were forced to do the best that they could under these conditions. The temperature was a trifle too low during the early winter months and in consequence the growth was slower than it would have been under higher temperature conditions. During January and February there was a much larger percentage of sunshine and the plants did fairly well during this time. From March on the weather was all that could be desired, and the berries were pushed on rapidly.

There was trouble with the plant aphis almost from the beginning of the experiment, and they were the source of much trouble. Since spraying would have added plant food, the experimenter tried killing off the insects by hand and he succeeded excellently in controlling the plant lice, but it entailed a great amount of extra work at a time when pollinating was going on. Fortunately there was no trouble from the red spider until the last week of the experiment. Spraying with K_2S, 3 ounces to 100 gallons, controlled these well enough. As the experiment was at the end the addition of the food in K_2S had no effect on the results.

Another difficulty that was encountered was that the first bloom of the strawberries had no pollen. Through the aid of Mr. Bailey of the Department of

Horticulture who is breeding strawberries, the necessary pollen was secured until it could be obtained from the plants. It was the intention to secure data from these flowers, that is, data on the length of anthers, the number of anthers, etc., but this unfortunate incident caused the work to be abandoned.

On account of the dary and cool weather, Pleurococcus, one of the blue green algae, grew on the top of the pot. These plants, however, soon died and left but a green tinge on the top layer of the pot, which aided in conserving moisture.

D A T A

LEAF DATA

As it has been described before, the leaf surface was taken in one general manner for the purpose of comparison rather than of securing accurate measurement of the leaf surfaces. The data on the leaves were taken three times, once at the time of planting, once in the middle of February, and lastly at the time of taking up the plants. The variation was found to be rather large. The leaf surfaces and average of the groups are given in the table below.

Table I — Leaf Surface (sq.cm.) — Nov.17

No. of pot	Leaf surface	No. of pot	Leaf surface	No. of pot	Leaf surface	No. of pot	Leaf surface	No. of pot	Leaf surface
1	84.20	7	69.13	13	50.61	19	95.12	25	70.16
2	110.34	8	100.17	14	110.22	20	72.08	26	60.04
3	60.12	9	100.04	15	90.41	21	105.62	27	90.26
4	100.07	10	80.30	16	75.62	22	100.41	28	80.33
5	72.02	11	72.01	17	65.02	23	70.23	29	90.65
6	59.25	12	104.35	18	70.84	24	60.18	30	78.47
Ave.	81		87		77.1		83.60		77

It will be seen on glancing over the data that the leaf surface of the groups is well nigh equal and that they have about the same amount of vigor. Pot number 31 had a surface of 85.24 while the other check pot, number 32, had a surface of 82.16.

Table II — Leaf Surface (sq. cm.) — Feby.14

No.of pot	Leaf surface	No.of pot	Leaf surface	No.of pot	Leaf surface	No.of pot	Leaf surface	No.of pot	Leaf surface
1	185.12	7	135.97	13	103.17	19	237.26	25	167.23
2	215.62	8	214.17	14	154.69	20	172.39	26	214.47
3	156.82	9	165.12	15	140.14	21	182.87	27	208.68
4	150.65	10	172.14	16	208.63	22	212.13	28	205.96
5	174.47	11	212.38	17	137.23	23	185.19	29	256.72
6	153.76	12	212.63	18	186.76	24	216.47	30	228.41
Ave.	171.74		185.40		155.11		201.55		213.74
Inc.over Table I	90.74		98.40		78.01		117.95		136.74

In spite of the cool wet weather during this growing period, the leaves made a vigorous growth, and although the gain in each group is fairly uniform, there is some variation in the increase in the leaf surface over that of November 17. The pots receiving the least plant food are making the most rapid gain in leaf growth. This may be due to the cloudy weather with little sunshine or it may be due to the food that the plants are obtaining. None of the plants have shown any ill-effects from the food and all appear to be thriving vigorously. In pots 31 and 32, the effect of no food is showing very widely. Both have but one-half of their former leaf surface and they have extremely small leaves. Each new leaf on pushing out is smaller than the preceding one. The plants are still living on the food stored in the roots, but that source of food appears to be rapidly exhausting itself, from the light color of the foliage. Judging from the appearance of the leaves, death seems to be almost at hand.

At this time pots number 6, 11, 15, 24 and 26 were taken up and their crown and root measurements recorded. They were then replanted in ordinary garden soil to complete their growth. In the subsequent data they are not to be treated with the other groups, but taken separately. They received no more plant food and were watered with ordinary hydrant water.

Table III					Leaf Surface (sq.cm.)				May 12
No.of pot	Leaf surface	No.of pot	Leaf surface	No.of pot	Leaf surface	No.of pot	Leaf surface	No.of pot	Leaf surface
1	535.20	7	253.20	13	461.52	19	905.91	25	575.64
2	553.80	8	324.46	14	370.50	20	568.88	27	420.61
3	217.83	9	401.86	16	1089.22	21	989.65	28	467.07
4	12.62	10	Dead	17	532.35	22	1119.74	29	502.21
5	Dead	12	420.12	18	436.14	23	255.13	30	548.68
Ave.	263.89		279.93		577.94		767.86		490.88
Inc.over Table II	92.15		94.53		422.83		566 31		277.14
Inc.over Table I	182.89		192.93		500.84		684.26		413.88
6	309.38	11	582.51	15	284.14	24	610.62	26	301.83

In glancing over the data it can be readily seen that the best growth was made by group IV. Up to February 14, the pots receiving the smallest amounts had made the greatest gain. It seems as if the lack of food had forced the plant

to use up its surplus supply more quickly than in the case of groups III and IV, especially the former. Group III seems to have lingered in the unfavorable weather and to have gained very rapidly with the favorable weather; it stood midway between groups IV and V at the end of the experiment in leaf production. Groups III and IV seem to have made a very heavy growth during the warmer weather following February 14, and toward the end of the experiment they were all vigorous and contained a good set of berries. Groups I and II seem to have slumped considerably, especially in the last few weeks. Nos. 4 and 5 of group I were in a weak condition for a considerable time. No. 5 finally died, while No. 4 was but a shadow of a plant whose roots were practically dead when the plants were taken up. No. 10 of group II fared in the same manner, and the plants in both of these groups did not appear to have the vigor that was shown by those in the other groups. The death of the plants decreased the general average, but it will be noted that the average would have been considerably lower than in the other groups had the dead plants been discarded from the results. All of the plants showed effect from what I think is overfeeding, and the most of the other plants in groups I and II would probably have died in time had the experiment been continued. A comparative estimate of the groups can be obtained from the illustrations on pages 28 and 29

Pot No. 6 seems to have started on the downroad before February 14, as some of the roots had died and the plant never regained its full vigor after that. Pot 11 had not felt the influence of too much food when it was removed, and it seems to have done nicely since that time in the garden soil. The other pots that had been taken out also showed much vigor and continued to grow without much check, but they were not nearly so vigorous as their former companions.

The check pots No. 31 and No. 32 gained slightly over their former leaf surface, but the growth was very feeble. Plant No. 31 was extremely vigorous and had much stored material in the roots when the experiment was started. This plant matured three small berries. The increase seems to have been made since

the middle of March, and my theory in regard to the matter is that the plant secured a very small amount of food by osmosis through the small drainage hole at the bottom of the pot from the food that had leaked into the sand from the other pots. This happened because the pots had no food whatsoever. The other pots could not have taken up any food in this manner, as the sand in the other pots was more saturated than the sand in which they were bedded.

There is not much doubt in my mind that the plants in groups I and II died from overfeeding as they showed the characteristic light color, first around the veins, then spreading throughout the whole leaf. The tips then gradually became burned and the leaf died back to the stem. Finally the stem died and lastly the crown succumbed. There was no sign of insect or fungous injury.

Data were also taken on single leaves in two pots of each group for a period of twenty-nine days from January 13 to February 11, and the gain showed approximately the same results as the leaf surfaces in Table II. Group V showed a gain of 12.78 cu.cm., group IV, of 10.26 cu.cm., group III, of 7.63 cu.cm., group II, of 7.29 cu. cm., and group I, of 7.46 cu.cm.

From the results of the leaf data then, group IV showed by far the best growth, group III was second, group V was third, and groups I and II were about equal, with group II slightly in the lead.

CROWN DATA

The crown data were taken but twice during the period of experimentation--when the plants were placed in the pots and when they were taken out. The measurement of one plant from each group was also taken on February 14, when one plant of each group was removed. The following tables show the data of the groups.

Table I - Nov. 17 - Size of Crowns (cm.)										Feb. 14	
No. of pot	Size	No. of pot	Size	No. of pot	Size	No. of pot	Size	No. of pot	Size	No. of pot	Size
1	1.	7	.8	13	1.	19	1.	25	.8	6	1.2
2	1.	8	1.2	14	.8	20	1.2	26	1.	11	1.2
3	1.2	9	1.2	15	.9	21	1.	27	.9	15	1.3
4	1.2	10	.8	16	1.	22	.8	28	.8	24	1.2
5	1.	11	1.	17	.8	23	.9	29	.9	26	1.2
6	1.	12	.9	18	.9	24	1.1	30	1.0		
Ave.	1.1		1.		.9		1.		.9		

Table II					Size of Crowns (cm.)				May 12	
No. of pot	Size	No. of pot	Size	No. of pot	Size	No. of pot	Size	No. of pot	Size	
1	1.4	7	1.	13	1.7	19	2.2	25	1.7	
2	2.6	8	1.5	14	2.2	20	1.4	27	1.6	
3	1.5	9	1.5	16	1.4	21	2.1	28	1.3	
4	1.2	10	---	17	1.6	22	2.	29	1.7	
5	---	12	1.3	18	1.7	23	1.2	30	1.5	
Ave.	1.3		1.		1.7		1.8		1.5	
Inc. over Table I	.2		.9		.8		.8		.6	
6	1.1	11	1.6	15	1.6	24	1.8	26	1.2	

As in the case of the leaf data, the crown data show an increase for groups III and IV that is higher than that of group V, while groups I and II are far behind. This shows that the plants are not so vigorous in the first two groups as in the case of the other groups.

In the check pots there was no growth of the crowns.

ROOT DATA

The root data were taken at the same time and the pots were managed in the same manner as in the crown data.

Table I - Nov. 17 - Length of Roots (cm.) Feb.14

No.of pot	Length	No.of pot	Length	No.of pot	Length	No.of pot	Length	No.of pot	Length	No.of pot	Length
1	180	7	243	13	225	19	224	25	144	6	377
2	240	8	330	14	220	20	225	26	154	11	385
3	96	9	232	15	261	21	320	27	112	15	390
4	264	10	220	16	279	22	192	28	168	24	200
5	240	11	208	17	144	23	126	29	136	26	279
6	176	12	279	18	176	24	120	30	168		
Ave.	199		218		217		201		147		

Table II Length of Roots (cm.) May 12

No.of pot	Length	No.of pot	Length	No.of pot	Length	No.of pot	Length	No.of pot	Length
1	448	7	261	13	286	19	585	25	560
2	650	8	384	14	320	20	506	27	348
3	312	9	396	16	980	21	660	28	446
4	Dead	10	Dead	17	436	22	765	29	418
5	Dead	12	516	18	532	23	352	30	524
Ave.	282		311		511		573		459
Inc.over Table I	83		93		294		372		312
6	310	11	408	15	418	24	460	26	380

The roots bear out the data from the other tables with the exception of the groups III and V. which are reversed in this case. This was probably due to the fact that some of the roots of the plants were more torn in group III than in group V. The records on this part of the plant are probably the most inaccurate, therefore I do not think that too much emphasis should be placed on this slight variation.

The check pots show long thin roots reaching toward the opening at the bottom, which leads me to conclude that they received some food from that source. The roots were few in number, as most of them had died.

In groups I and II, the roots were partly dead and did not look very healthy, especially in group I. Group IV showed very vigorous roots with numerous fibrous rootlets, while groups III and V were close competitors for second place in this regard.

BERRY DATA

1-Formation of Berries

It was my intention to secure data on various factors of flower production but, as explained before, circumstances would not permit of it. However, the number of anthers, the number of petals, and the number of sepals were counted on each flower for a time. It was found that these data were all about the same. There was a little variation once in a while, but this was found on all plants, so the writer discontinued this part of the data. Records were taken on the date of opening of the flower, the date of pollinating, the number of flowers pollinated on each plant, and the number of fruits that set on each plant. This work was accomplished with as great accuracy as possible and the berries showed the results of the careful hand pollinating, as but few were imperfect. The work was all done by hand as no bees were allowed in the greenhouse. The sepals were removed to facilitate the work of pollinating. The pollen used was secured from some crosses that were in the same greenhouse. The intention was to use the pollen of the anthers of the plants in the experiment, but unfortunately the first few flowers of each plant had no filled anthers. Later this form of pollen was used and did the work nicely. The berries formed quickly and very few of the flowers did not set. The temperature and sunlight conditions during the pollinating period were as good as could be wished, as the dark cloudy days were few and the temperature in the greenhouse often ran up to 80 degrees. The following tables show the result of the data secured. In each plant the number of days from the date of opening of the first flower to the opening of the last flower, was taken. Also the number of days it took to pollinate each plant, the number pollinated on each plant, and the number of fruits of each plant that set were taken.

FORMATION OF BERRIES

No. of pot	Opening of flowers (days)	Pollinat- in (days)	Number Pollin- ated	Number set	No. of pot	Opening of flowers (days)	Pollin- ating (days)	Number pollin- ated	Number set
1	17	16	11	11	7	40	45	8	8
2	27	17	11	9	8	31	23	14	14
3	26	21	12	10	9	46	30	12	10
4	38	38	11	6	10	42	39	9	5
5	31	28	7	8	12	37	37	14	12
Ave.	28	24	10	8	Ave.	39	35	11	9
13	38	32	15	11	19	51	42	10	7
14	28	26	10	7	20	27	19	11	11
16	34	32	12	12	21	36	23	9	8
17	33	20	10	8	22	31	26	11	10
18	53	48	10	9	23	49	37	15	13
Ave.	37	32	11	9	Ave.	38	29	11	10
25	25	16	11	11	6	32	25	9	7
27	45	34	16	9	11	31	23	12	11
28	49	41	15	10	15	47	30	10	9
29	34	41	13	10	24	30	23	10	9
30	43	36	12	10	26	39	33	12	11
Ave.	39	33	13	10					

There is but little variation in the data in the above table, and that is such as might occur in plants under the same treatment. Group I is slightly lower than the rest, but as the remainder of the data proved, it is not due to the treatment, but to some other conditions which I do not know positively.

1 - Fruit Production

The climax to the data heretofore given and the records that are of the greatest interest are those on the production of fruit. The test in an experiment of this kind comes in the period of time that the fruit is harvested. These records decide whether or not the rest of the data has any direct bearing on the final results.

The length of the stems and the number of fruits on each branch were at first found, but again, these data seemed to depend on the individual plant and not to be influenced by the treatment given the pots. The factors in the fruit production that are of real value to the experiment are the weight of the berry, the date of ripening of the fruit, and the size of the berry. In the date of ripening, the number of days variation in the ripening of the berries of one plant from the first to the last was taken. In the size of the berry, the same method of measurement was taken as in the case of the leaf surfaces.

In this, only the first crop of strawberries was taken, as time did not permit the taking of data on the second crop, which according to my estimate would not have been finished until June, when the period of experimentation will be passed. The results would probably have substantiated the results found in the data below.

$NaNO_3$ was added about blooming time in an amount that corresponds to 100 pounds to the acre. It was added to two pots in each group, but the results do not show any apparent difference from the pots that were not treated. This was probably due to the fact that there was sufficient nitrogen in soluble form and that the plant did not require any additional nitrogen.

Below are the data on the production of fruit.

Fruit Production

No. of pot	Wt. of berry (grams)	Number of berries	Days of Ripening	Size of berry (sq.cm.)	No. of pot	Wt. of berry (grams)	Number of berries	Days of Ripening	Size of berry (sq.cm.)
1	6.599	11	11	5.93	7	6.121	8	19	6.51
2	6.599	9	15	6.05	8	5.245	14	18	5.75
3	4.699	10	17	5.08	9	5.735	10	13	6.09
4	2.443	6	4	3.62	10	2.865	5	10	3.95
5	1.433	3	5	2.46	12	6.047	12	28	5.99
Ave.	4.354	8	10	4.63	Ave.	5.202	10	17	5.66
*13	5.092	11	13	5.27	19	9.202	7	23	9.38
14	6.690	7	10	7.07	20	8.017	11	13	7.43
*16	7.157	12	18	7.29	21	9.160	8	6	8.14
17	7.045	8	10	6.92	22	7.419	10	9	7.18
18	7.127	9	19	7.21	23	5.578	13	9	5.47
Ave.	6.622	9	14	6.71	Ave.	7.875	10	12	7.52
25	7.109	11	10	6.30	6	6.441	7	9	4.81
27	6.801	9	14	6.47	11	5.336	11	8	5.75
28	7.394	10	16	6.07	15	3.818	9	11	4.95
29	6.251	10	20	6.62	24	4.724	9	15	5.38
30	6.718	10	10	6.96	26	5.023	11	15	5.24
Ave.	6.854	10	14	6.48					

* = One berry not fully ripe.

As it was found in the previous data, group IV is far superior to the remaining groups in production of fruit. This corresponds to the expected estimate. The plant that has the most vigorous growth will naturally produce the most fruit if the strength of the plant does not run into leaf production. The plants must be nourished well enough so that there is no reduction of one factor to benefit another.

There is some variation in groups III and V from the data found in the leaf surface. In the size of the berries the same relation holds as in the leaf surfaces, but in the weight of the berry, group V takes the lead slightly. That the berries are more compact is shown from the records taken. Why this is true I do not know, unless it could be that group III threw its strength more into leaf production because of an over-supply of food, while group V utilized the food for berry production at the expense of leaf production. As the object of growing strawberries is to produce berries, this group would seem to be preferred over group III. The number of berries is practically the same in all cases. It

would seem that group IV ripens closer together than the immediately surrounding groups; group I, however, shows a better result than do any of the others. But since the first two groups had a number of dead plants, this advantage may not have occurred if this had not been true.

That the results are due to the treatment accorded the plants may be seen from the production in the case of pots No. 6, 11, 15, 24, and 26, which before February 14 belonged to the above groups.

The check pots No. 31 and 32 add their little share to the general results. Pot 31, which contained a very vigorous plant when the experiment began, produced but three small berries, weighing 2.161 grams on the average, with an average surface of 2.87 sq. cm.

See the illustrations on pages 28 and 29.

CONCLUSIONS

That the one group of plants, namely, group IV, stands far ahead of the other groups, is readily seen in the tables of data on the various parts of the plant. Groups III and V are competitors for second place, with group III slightly in the lead. The other two groups are far out of the range of the last three and with continued treatment would probably show even a more distinct difference. From the data the conclusion is drawn that the difference between the groups is due mainly to the treatment that has been accorded the various sets of pots.

It would seem that the amount of plant food that will produce the best crop of berries and yet keep the leaf and root parts of the plant in a most vigorous condition would correspond more nearly to the amount of plant food added to group IV than to any other group in the experiment. Both groups V and III show that they have too little or too much and groups I and II show decidedly the effect of too much soluble food.

The plant food added in this experiment is of rather soluble nature and is very available to the plants. Under field conditions probably twice as much food can be added with safety but it may not be necessary to use so much. Too much money spent on fertilizers will but decrease the profit to the grower. The best recommendation to the grower would be to find out just what amount of food his crop uses in one season and then see to it that the necessary amount of available plant food is in the ground before the plant needs it. Usually the food should all be added before the blooming time, as the plant takes up little soluble food after that.

The nature of the fertilizer must be known. Dried blood and sodium nitrate are used up so quickly that they will kill a plant if they are not employed with caution. These forms of plant food can be added sparingly at critical times in the life of the plant. And then fertilizers have an effect on each other that is not well known as yet.

The elements of commercial importance added in this experiment are nitrogen, phosphorus, and potassium. The best results were shown where, in pounds to the acre, 1006 of nitrogen, 314 of phosphorus, and 628 of potassium were added. As there was no food in the soil and as much of this food leaked out, it is safe to say that the plants did not use all of this food. If a strawberry soil is found to contain about twice as much nitrogen and phosphorus and about ten times as much potassium, it would hardly be necessary to add more plant food than is taken from the ground by the crop each year. In this way the maximum crops can be produced.

An analysis of the strawberry shows that the phosphoric acid in the plant is .11 per cent, the potash .30 per cent, and the nitrogen is .15 per cent. The vine shows .48, .35, and 1 per cent respectively. From the weight of the berries and vines, the grower can calculate just what he must add each year.

From the distinct results found it seems that this mode of experimenting could be used to advantage. With better facilities an experiment of this nature could be carried on on a larger scale, and more definite results could be obtained.

Pots No 4 and 5 of group I. Note the poor condition of the plants. No.5 died soon after this picture was taken, and No.4 had but a single set of leaves left. Most of the leaves are brown and the berries are withered

Pots No. 9 and 10 of group II are rather characteristic of the group. No. 10 died about the same time that No. above did. No. 9 is about the most vigorous plant of the group.

Pots No. 16 and 18 are typical of group III. No. 16 in particular is very vigorous. No. 18 is one of the poorest plants of the group. The leaves are very upright. The root system of these plants is excellent.

Nos. 21 and 22 of Group IV show the characteristic heavy production of leaf and berry of this group. Note the general vigor of the plants.

Nos. 29 and 30 of Group V show some vigor but they do not compare with the above plants of Group IV. They are very excellent plants, however, and are heavy yielders of fruit.

Nos. 31 and 32, the check pots, received no plant food and were watered with distilled water.